I claim:

1. A method of forming a polymer nanocomposite comprising the steps of:

selecting a clay having a layered structure and a polymer, said selecting satisfying

$$|S_p - S_{scf}| > |S_c - S_{scf}| \text{ and } |S_c - S_{scf}| \leq 2.0\ (\text{cal/cm}^3)^{0.5},$$

wherein S_p is a solubility parameter of the polymer, S_c is a solubility parameter of the clay; and S_{scf} is a solubility parameter of a supercritical fluid (SCF);

mixing the polymer and the clay to form a polymer-clay mixture;

melting the polymer-clay mixture to form a polymer-clay melt;

initially contacting the polymer-clay melt with the SCF while the SCF is subject to an initial pressure exceeding the critical pressure of the SCF and to a temperature exceeding the critical temperature of the SCF; and

after said initially contacting step, further contacting the polymer-clay melt with the SCF while the SCF is subject to a lower pressure that is less than the critical pressure of the SCF so as to exfoliate the clay to form the nanocomposite having the exfoliated clay being substantially dispersed throughout the polymer-clay melt.

2. The method of claim 1, wherein during the initially contacting and further contacting steps the SCF is subject to a pressure which decreases monotonically from the initial pressure to the lower pressure.

3. The method of claim 1, wherein during the initially contacting and further contacting steps the SCF is subject to a pressure which decreases non-monotonically from the initial pressure to the lower pressure.

4. The method of claim 1, wherein during the initially contacting and further contacting steps the SCF is subject to a pressure which varies essentially continuously from the initial pressure to the lower pressure.

5. The method of claim 1, wherein during the initially contacting and further contacting steps the SCF is subject to a pressure which varies essentially discontinuously from the initial pressure to the lower pressure.

6. The method of claim 1, wherein the initially contacting and further contacting steps include flowing the polymer-clay melt and the SCF within an extruder and through a first region along a screw comprised by the extruder and through a second region in the extruder beyond screw such that the polymer-clay melt and SCF exit the extruder at a bounding surface of the second region to a third region outside the extruder.

7. The method of claim 6, wherein the lower pressure exists within the first region.

8. The method of claim 6, wherein the lower pressure does not exist within the first region, and wherein the lower pressure exists within the second region.

9. The method of claim 6, wherein the lower pressure does not exist within the extruder, and wherein the lower pressure exists within the third region.

10. The method of claim 1, wherein during the initially contacting step the SCF preferentially migrates toward the layered structure of the clay.

11. The method of claim 1, wherein mixing the polymer and the clay is performed using a co-rotating twin screw extruder.

12. The method of claim 11, wherein the co-rotating twin screw extruder operates at a temperature range from about 200 °C to about 250 °C, a screw speed from about 200 rpm to about 500 rpm, and a throughput from about 10 kg/hr to about 400 kg/hr.

13. The method of claim 11, wherein a die of the co-rotation twin extruder operates at a temperature from about 200 °C to about 270 °C.

14. The method of claim 1, wherein the polymer is selected from a group consisting of high density polyethylene, low density polyethylene, nylon 6, nylon 6, 6, poly(acrylonitrile), poly(ethylene terephthalate), poly(acetal), poly(propylene), polystyrene, poly(vinyl acetate-co-vinyl alcohol), poly(vinylidene chloride), poly(vinylidene fluoride), and poly(vinyl alcohol).

15. The method of claim 1, wherein the clay comprises at least one of an aliphatic fluorocarbon, perfluoroalkylpolyether, quarternary ammonium terminated poly(dimethylsiloxane), an alkyl quarternary ammonuim complex, glass fibers, carbon

fibers, carbon nanotubes, talc, mica, natural smectite clay, synthetic smectite clay, montmorillonite, saponite, hectorite, vermiculite, beidellite, or stevensite.

16. The method of claim 1, wherein the supercritical fluid comprises at least one of a hydrodcarbon, a cholrinated hydrocarbon, a fluorinated hydrocarbon, a chlorofluorohydrocarbon, an alcohol, a ketone, an ether, CO_2, H_2O, N_2, or O_2.

17. A system for forming a polymer nanocomposite, comprising:

a polymer-clay melt of a clay having a layered structure and a polymer; and

a supercritical fluid (SCF) in physical contact with the polymer-clay melt, wherein the clay, the polymer, and the SCF collectively satisfy $|S_p - S_{scf}| > |S_c - S_{scf}|$ and $|S_c - S_{scf}| \leq 2.0\ (\mathrm{cal/cm^3})^{0.5}$, and wherein S_p is a solubility parameter of the polymer, S_c is a solubility parameter of the clay; and S_{scf} is a solubility parameter of the SCF.

18. The system of claim 17, wherein the SCF is subject to a pressure exceeding the critical pressure of the SCF and to a temperature exceeding the critical temperature of the SCF.

19. The system of claim 17, wherein the SCF is subject to a pressure less than the critical pressure of the SCF.

20. The system of claim 17, wherein the polymer-clay melt and the SCF are flowing together in a same direction.

21. The system of claim 20, further comprising an extruder, wherein the extruder includes a first region and second region, wherein the first region has a screw therein, wherein the second region extends from an end of the first region to an end of the extruder, and wherein the SCF is flowing within the first and second regions of the extruder.

22. The system of claim 21, wherein the SCF is subject to a pressure exceeding the critical pressure of the SCF and to a temperature exceeding the critical temperature of the SCF while flowing in the first region.

23. The system of claim 21, wherein the SCF is subject to a pressure exceeding the critical pressure of the SCF and to a temperature exceeding the critical temperature of the SCF while flowing in the second region.

24. The system of claim 21, wherein the SCF is subject to a pressure less than the critical pressure of the SCF while flowing in the second region.

25. The system of claim 21, wherein the SCF is subject to a pressure exceeding the critical pressure of the SCF and to a temperature exceeding the critical temperature of the SCF while flowing in the first and second regions.

26. The method of claim 17, wherein the polymer is selected from the group consisting of high density polyethylene, low density polyethylene, nylon 6, nylon 6, 6, poly(acrylonitrile), poly(ethylene terephthalate), poly(acetal), poly(propylene), polystyrene, poly(vinyl acetate-co-vinyl alcohol), poly(vinylidene chloride), poly(vinylidene fluoride), and poly(vinyl alcohol).

27. The method of claim 17, wherein the clay comprises at least one of an aliphatic

fluorocarbon, perfluoroalkylpolyether, quarternary ammonium terminated poly(dimethylsiloxane), an alkyl quarternary ammonuim complex, glass fibers, carbon fibers, carbon nanotubes, talc, mica, natural smectite clay, synthetic smectite clay, montmorillonite, saponite, hectorite, vermiculite, beidellite, or stevensite..

28. The method of claim 17, wherein the supercritical fluid comprises at least one of a hydrodcarbon, a cholrinated hydrocarbon, a fluorinated hydrocarbon, a chlorofluorohydrocarbon, an alcohol, a ketone, an ether, CO_2, H_2O, N_2, or O_2.